CS 224 Home Assignment 01 - Option 1

Wireless networks + FTP/CBR through ns3

Due: Nov 7th 2020

This lab* will proceed in the following phases.

1) *First, you will be given time to write and run your code, answer the questions, and type your answers below the questions, in this odt file.*
2) *You **MUST export your ODT to PDF and SUBMIT the PDF file and code on BodhiTree.***
3) *A **viva** will be scheduled separately for each team member. Final marks are almost entirely based on the viva*

**Please do Background Lab 1 and 2 before coming here.*

## Instructions for running ns3 on CSE machines from CSE Sysads

A) Given ns3 Code Comprehension:
Start with the `assignment1-ns3.cc.` file given to you. Study this file and answer the following questions.

1. How many nodes are there in the network?
   4

2. What is the physical layer medium through which they are connected?
   Wireless

3. Which IEEE wifi standard is the medium set to?
   802.11a

4. What is the PHY data rate ("bandwidth" or "transmission rate") of the medium set to ?
   54Mbps

5. What is the node topology implemented in the given file? (which node is physically connected to which node(s))
Each node is connected to every other node with 50dB loss. The topology is as follows:

```
   n1
  / | \
 /  |  \
n0--|-- n2
 \  |  /
  \ | /
   n3
```
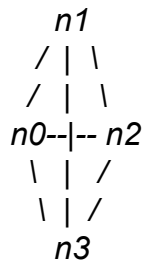
6. What application(s) are running on the node(s)? In the terminology used in the ns3 code, which represent(s) "constant bit rate" (CBR) flow and which one represent(s) "file transfer" (FTP) flow (if any)?
Node 0 (10.0.0.1) & Node 1 (10.0.0.2) run the OnOffHelper application, which involves CBR flow
Node 2 (10.0.0.3) & Node 3 (10.0.0.4) run the BulkSendHelper application, which involves FTP flow. Node 2 is the source, while Node 3 is the sink.

7. What are their transport layers?
CBR -> UDP
FTP -> TCP

8. Based on your theory + previous labs knowledge - which app+transport layer combination performs RDT (Reliable Data Transmission)?
FTP (application layer) with TCP (transport layer)

9. Based on your theory + previous labs knowledge - which app+transport layer combination does not provide RDT?
CBR (application layer) with UDP (transport layer)

10. What are the input traffic parameters of the FTP source (data rate, maximum packet size, bulk data maximum bytes, window size etc as applicable.) ?

Bulk Data Maximum Bytes	*600000*
Window Size	*1100 bytes*

11. What are the input traffic parameters of the CBR source (data rate, maximum packet size, bulk data maximum bytes, window size etc as applicable.) ?

Data Rate	*10 Mbps*
Maximum Packet Size	*2200 bytes*

12. For the applications configured in the code, write down the source and destination port numbers, if they are possible to be determined from just studying the simulation code (not running it). If it cannot be determined, write "Cannot be determined from the code".
    CBR:
    Source Port: Cannot be determined from code
    Destination Port: 12345 (on Node 1 with IP 10.0.0.2)

    FTP:
    Source Port: Cannot be determined from code
    Destination Port: 54321 (on Node 3 with IP 10.0.0.4)

13. What are the approximate start times of the sources (round to integer)?
    Start time for CBR source = 1 sec
    Start time for FTP source = 1 sec
    When OnOffApplication is started, the first packet transmission occurs after a delay equal to (packet size/bit rate).

B) Given ns3 simulation experiment baseline.
    Run the given ns3 simulation code. Answer the following questions. (Copy paste from terminal is ok. Ctrl-Ins for copy, Shift-Ins for paste).
14. How many flows are reported by Flow Monitor?
    3

15. Explain what each flow represents. (Write/copy-paste the IP address, port parameters, and describe briefly what that flow is).
    Flow 1 (10.0.0.3, 49153 -> 10.0.0.4, 54321): FTP flow from source to sink
    Flow 2 (10.0.0.1, 49153 -> 10.0.0.2, 12345): CBR flow
    Flow 3 (10.0.0.4, 54321 -> 10.0.0.3, 49153): Acks for FTP flow from sink to source

16. In case you could not determine some port numbers from just looking at the code, write down the port numbers now, stating which port numbers they are. (E.g. "nnnnnn: Destination port of source XYZ running on Node N with IP address a.b.c.d)
    49153: Source Port of CBR source running on Node 0 with IP 10.0.0.1

49153: Source Port of FTP source running on Node 2 with IP 10.0.0.3

17. What is the observed throughput and how does it differ from the offered data rate (Input load) for the CBR flow?
    Observed Throughput (for CBR flow) = 9.65763 Mbps
    This is slightly lesser than the Input Load (9.66055 Mbps) as well as the Data Rate (10 Mbps)

18. What is the observed throughput for the FTP flow?
    Observed Throughput (for FTP flow) = 7.7055 Mbps

19. What is the file transfer delay for the FTP flow? (This metric is not being calculated, you have to add this calculation in your code. See the code for hint).
    File Transfer Delay for FTP Flow = 0.651897 s

(Make a copy of the given code for backup, or make any change only by commenting code)

*Now disable **only FTP** flow and answer the following questions:*
20. Find the maximum throughput possible for one CBR flow when there's nothing else on the network. Do this by increasing the CBR data rate parameter.
    Maximum throughput possible for one CBR flow = 24.6 Mbps

*Now disable **only CBR** flow and answer the following questions:*
21. For a given file size (600000bytes), and given link+phy layer what parameter of the FTP flow in this code can you change to give you better throughput and smaller file transfer delay? (Study the code comments and answer this properly.)
    Sliding Window Size (given by the variable `senderWindowSize`)

22. What's the maximum throughput you were able to get for this file size? (Round to single decimal point)
    Maximum FTP throughput = 12.56 Mbps [At `senderWindowSize` = 4000]

23. What's the minimum file transfer delay you were able to get for this file size? (Round to single decimal point)
    Minimum file transfer delay = 0.4 seconds [At `senderWindowSize` = 4000]

C) Modified n3 wifi simulation for configurable scale.
Now modify the given simulation so that you have multiple simultaneous FTP and CBR flows in the following topology. Suppose you have M nodes (assume M will be a multiple of 4). M/2 nodes will be involved in CBR traffic, M/2 in FTP. Among the M/2 nodes of CBR there will be M/4 source-destination pairs, and similarly for FTP. E.g. for an 8 node simulation, nodes n0-n3 could be CBR nodes, n4-n7 could be FTP nodes. In this example (n0,n1) and (n2, n3) could be two CBR

source-destination pairs and (n4,n5) and (n6,n7) could be two FTP source-destination pairs. Note that how you number the nodes for your programming convenience is **your choice.** You only have to make sure the numbers and topology of flows is correct.

Now let the file size for FTP transfer as was given (600KB), other parameters set to the value that gave you the maximum throughput and minimum delay when only one FTP flow was using the network. Shut off the CBR flows. Find metrics as a function of increasing M_{ftp} , the number of **FTP data sources.** *Ensure you set M properly to get your desired* M_{ftp}

24. For this scenario, what is the maximum total channel throughput you got?
   Maximum total channel throughput = 16.9962Mbps

25. What was the smallest M_{ftp} you got this maximum at?
   Smallest M_{ftp} = 2

26. At this M_{ftp}, what was the average file transfer delay over all the flows?
   Average file transfer delay = 0.893468 seconds

Now set the data rate of the CBR flow to 2Mbps. Shut off the FTP flows. Find metrics as a function of increasing M_{cbr}, the number of **CBR data sources.** *Ensure you set M properly to get your desired* M_{ftp}

27. For this scenario, what is the maximum total channel throughput you got?
   Maximum total channel throughput = 25.2225Mbps

28. What was the smallest M_{cbr} you got it at?
   Smallest M_{cbr} = 9

29. At this M_{cbr}, what was the average throughput per flow?
   Average throughput per flow = 2.8025Mbps

D) ns3 wifi simulation with high CBR and FTP traffic. Now turn on all flows, in the ratios mentioned earlier (Half CBR pairs, Half FTP pairs), with parameters as before (Ftp file size = 600000 bytes, CBR date rate = 2 Mbps, and keep increasing M and noting metrics.

30. What is the smallest M that gives you the maximum *total* channel throughput?
   Smallest M = 28

31. What was the maximum *total* channel throughput?
   Maximum total channel throughput = 23.3333Mbps

32. ~~What was the **average file transfer delay for FTP flows only?**~~

33. How does this maximum throughput compare with the maximum achieved by only multiple CBR flows and only multiple FTP flows?
This is much higher than the maximum achieved only through multiple CBR or multiple FTP flows

34. At this maximum level, what percent of the total channel throughput is used by all of the FTP data flows?
FTP flows account for 47.92% (11.1809 Mbps) of the total channel throughput

35. What is the average file transfer delay?
Average file transfer delay = 2.47327 seconds

36. What's the factor difference of the file transfer delay (X) from the best (lowest) delay that you got from the single flow experiment (Y)? If X = f *Y, write f.
f = 6.183

37. What is the total CBR throughput over all sources?
    a. What's the factor difference from the best (highest) throughput (X) that you got from the single flow experiment (Y)? If X = f *Y, write f.

    Total CBR throughput = 12.1524 Mbps
    f = (12.1524 / 24.5586) = 0.495

Submit your code and this file (as pdf) by tarring it into a file assignment01.tar and upload on Bodhitree.

Next, enter these answers in the SAFE quiz. Grading will be manual but we need this for efficient evaluation.

Uploading the answer pdf AND SAFE quiz submission is <u>compulsory</u> for viva eligibility. SAFE quiz submission should by done by each team member.

Instructions for running ns3 from CSE Sysads

Installation path of ns3 : /opt/ns-allinone-3.30/ns-3.30

Here are the instructions for students to login into sl2 lab machines and run ns3 programs.

With VPN:

1) Open up terminal or CMD
2) Login to sl2 lab machines using cse_username@sl2-machineno@cse.iitb.ac.in where cse_username is your cse ldap and sl2-machineno is the machine which you want to login to.
Eg: If my cse ldap is shailendra and I want to login to sl2-20 then the above command will be shailendra@sl2-20.cse.iitb.ac.in
3) To run a sample ns3 program, run the below commands.
cd /opt/ns-allinone-3.30/ns-3.30
./waf --run hello-simulator

If you get output like below then you have successfully executed ns3 sample program

'build' finished successfully (1.374s)
Hello Simulator

Without VPN:

Login to login server using ssh cse_username@login.iitb.ac.in -p 5022 where cse_username is your cse ldap. Rest of the steps are same step 2 and step 3 with VPN

You can login to any of the below sl2 machines

[sl2-10 , sl2-13 , sl2-15 , sl2-17 , sl2-20 , sl2-24 , sl2-25 , sl2-26 , sl2-27 , sl2-37 , sl2-39 , sl2-40 , sl2-43 , sl2-45 , sl2-46 , sl2-47 , sl2-48 , sl2-49 , sl2-50 , sl2-51 , sl2-52 , sl2-54 , sl2-55 , sl2-58 , sl2-59 , sl2-60 , sl2-61 , sl2-63 , sl2-64 , sl2-66 , sl2-67 , sl2-69 , sl2-72 , sl2-73 , sl2-74 , sl2-75 , sl2-79 , sl2-80 , sl2-81 , sl2-84 , sl2-86 , sl2-87 , sl2-9 , sl2-91 , sl2-93 , sl2-96 , sl2-97 , sl2-98 , , sl2-101 , sl2-103 , sl2-105 , sl2-107 , sl2-108 , sl2-109 , sl2-11 , sl2-110 , sl2-112 , sl2-114 , sl2-115 , sl2-116 , sl2-117 , sl2-118 , sl2-119 , sl2-12 , sl2-120 , sl2-121 , sl2-122 , sl2-123 , sl2-124 , sl2-125 , sl2-126 , sl2-127 , sl2-128 , sl2-129 , sl2-130 , sl2-132]

Instructions for transferring files from your laptop to sl2 machines

Linux
1. Login to IITB VPN
2. In file manager go to Connect to server (maybe thru "Other Locations") and give sftp://mars.cse.iitb.ac.in/
   As the server, login with your login and password.
   Now your home directory will be displayed like a local directory in File manager.
   Now you can copy-paste as usual.
3. Navigate to the ns3 directory above, copy your code file to the required ns3 directory.
4. Open a terminal on some sl2 machine and run ns3 as per instructions above.
5. Now you can even 'double-click' on the code file on sl2 and the editor will open in your laptop and you can directly edit the code file.

Windows
Check this: https://winscp.net/eng/index.php